Final Technical Report for NASA Grant NAG5-12924 Going to the Bottom of the Explosion that Formed Cas A

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The purpose of this INTEGRAL AO1 proposal was to observe the gamma-ray lines at 1157 keV, as well as 68 keV and 78 keV of the ^{44}Ti decay chain from the youngest known galactic supernova remnant Cas A. The radioactive decay of ^{44}Ti in Cas A was first detected by COMPTEL in the 1157 keV line[1] and later confirmed in the lower energy lines using BeppoSAX data[2]. Despite the second confirming mesaurement, the flux value still has a considerable error, due to a low signal over background ratio and the poor definition of the continuum background in the range of 70 – 100 keV above the line energies. In addition to improving this flux measurement, INTEGRAL has the unique capability, in principle, to measure the line width of the emission. This type of measurement can further constrain supernova explosion models. Unfortunately, the INTEGRAL instrumental background, especially in the SPI spectrometer, turned out to be significantly higher than estimated at the time of proposal submission[3, 4] before launch. This, and to a smaller extent the reduced effective exposure time of about 1.5 Ms compared to requested 2.5 Ms, has precluded us from reaching the sensitivity necessary for this measurement. Studies of the background variability with the goal of improving background modeling are ongoing, and additional 2.5 Ms observing time has just been approved for the next observing cycle.

Fig. 1 clearly shows Cas A as a strong continuum source in hard X-rays from 20–50 keV, using the INTEGRAL/IBIS imager. A spectra of Cas A in the range of 20–120 keV with IBIS, depicted in Fig. 2, shows a broad "bump" on top of the power law extrapolation of continuum emission defined at lower energies. This spectral feature is consistent with emission observed by BeppoSAX/PDS[2], which is overlayed in grey in this figure. At the current stage, the IBIS measurement is still less significant than the BeppoSAX measurement, but the fine spatial

Figure 1: INTEGRAL/IBIS 20–50 keV continuum image of part of the Cas A field. The circle identifies Cas A.

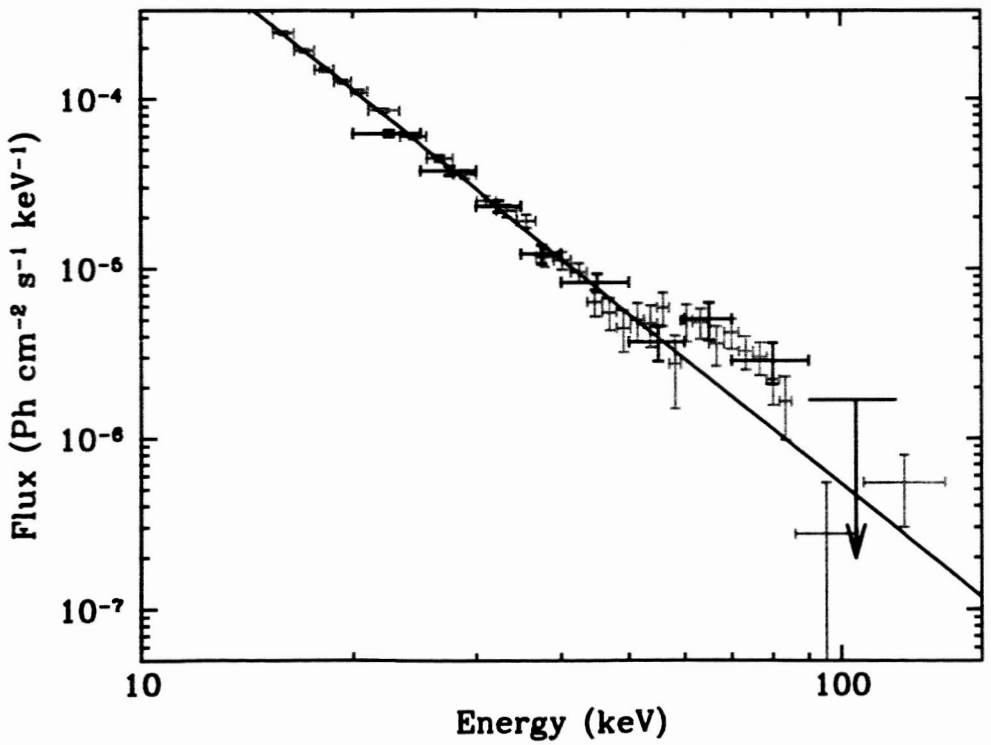

Figure 2: Cas A spectra: INTEGRAL/IBIS (black) and BeppoSAX/PDS (grey).

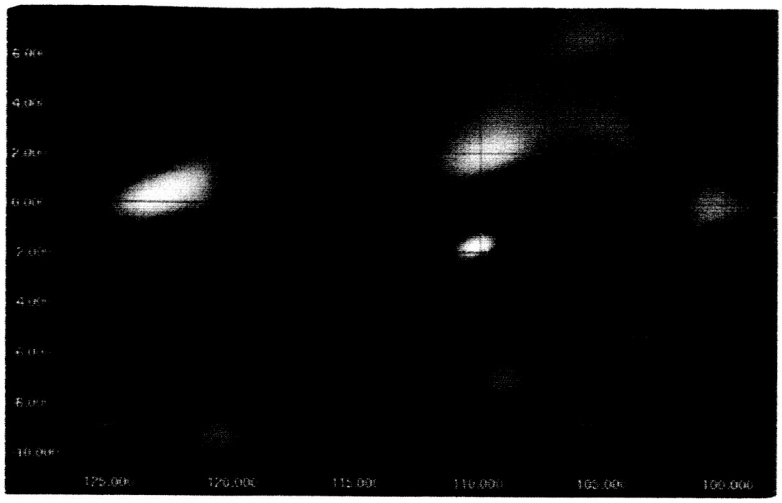

Figure 3: INTEGRAL/SPI Cas A image in the 1142–1172 keV energy range, in which a broadened line of ^{44}Ti would be expected most prominent. The circle indicates Cas A, but it is not a detection. The peak brightness has a significance of 2.5σ and corresponds to a flux of $7 \times 10^{-5}\,\gamma\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$.

resolution of IBIS constrains the emission better to the Cas A remnant. With greatly improved observing time, we hope to measure the continuum at energies above the 68 keV and 78 keV lines, so that better information on total flux, line width, and spatial extent of line emission will become available.

Fig. 3 shows an example of our search for the 1157 keV line with the spectrometer SPI. This image is taken in an energy window of 30 keV around the line energy, which would capture any line broadened up to about 3% FWHM. The brightest feature in the map is close to the Cas A position, but by itself, at the current stage, cannot be claimed a detection, as the significance is only 2.5σ. This would correspond to a rather high flux value of $7 \times 10^{-5}\,\gamma\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$. Again, the future increase in observing time should produce a clear detection also for SPI, and should allow a measurement of the line width. Already at this point, we can set an upper flux limit of only $1.8 \times 10^{-5}\,\gamma\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}(2\sigma)$ for a *narrow* line from Cas A (1155–1159 keV).

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